

MISCELLANEOUS FIELD STUDIES MAP MF-2419  
Version 1.0

U.S. DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY

Base from U.S. Geological Survey, 1952  
Revised 1993  
Polyconic projection, 1927 North American datum  
10,000-foot grid based on New Mexico coordinate system,  
central zone; 1,000-meter Universal Transverse Mercator grid ticks, Zone 13

CONTOUR INTERVAL 20 FEET  
NATIONAL GEODETIC VERTICAL DATUM OF 1929  
1993 MAGNETIC NORTH DECLINATION 10.5 DEGREES EAST AT CENTER OF MAP

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GEOLOGIC MAP OF THE PUYE QUADRANGLE, LOS ALAMOS, RIO  
ARRIBA, SANDOVAL, AND SANTA FE COUNTIES, NEW MEXICO

By  
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## DESCRIPTION OF MAP UNITS

General notes: Gravel in the Santa Fe Group is composed of (1) pink granite, pegmatite, amphibolite, sparse clasts of sedimentary rock, and minor fragments of epidote derived from Precambrian terrane to the northeast and east of the quadrangle; and (2) gray volcanic rocks, mainly of intermediate composition, derived from Tertiary volcanic terrane to the north. Axial-river gravel in the Puye Formation and in Quaternary alluvial and channel deposits consists mainly of (1) quartzite, granite, metavolcanic rocks, and pegmatite derived from Precambrian terrane to the north (Griggs, 1964); (2) lesser amounts of northern Tertiary silicic and intermediate volcanic rocks; and (3) less than 5 percent basalt and dark- to light-colored chert. Piedmont gravel consists mainly of dacitic rocks eroded from the Tschicoma and Puye Formations, lesser amounts of pumice eroded from the Bandelier Tuff, and pumice and obsidian from the tuffaceous deposits of the Cerro Toledo interval of time (that is, after eruption of the Otowi Member and before eruption of the Tshirege Member of the Bandelier Tuff). I use “Piedmont alluvium of the Cerro Toledo interval” as a shortened form of “Tephra and volcaniclastic sediments of the Cerro Toledo interval,” the name recommended by investigators from Los Alamos National Laboratory (see Broxton and Reneau, 1995, p. 11) for alluvial and epiclastic deposits that were deposited between eruptions of the two members of the Bandelier Tuff. Smith and others (1970) referred to these deposits as “tuffs and associated sediments” of the Cerro Toledo Rhyolite, but in the Puye quadrangle these deposits are chiefly dacitic alluvium derived from the Tschicoma Formation to the west. Geologic units are described as observed in gravel pits and pumice mines.

## MAN-MADE DEPOSITS

**f Fill (Holocene)**—Recent sand, gravel and other compacted construction materials beneath roadways. Thickness probably 3–8 m. Present beneath State Routes 502 and 30, but mapped only at their intersection

## STREAM ALLUVIUM

**Qal Channel and flood-plain deposits of the Rio Grande and tributary rivers (Holocene)**—Cross- to planar-bedded sand, pebbly sand, pebble to cobble gravel, and thin beds of silty sand exposed along the Rio Grande, Rio Pojoaque (immediately east of Rio Grande), and beneath adjacent low terraces (<4 m). Beds generally less than 0.5 m thick. Exposed thickness 2–4 m in the southeastern part of map area. Actual thickness probably more than 10 m along the Rio Grande. Base not exposed. Soils thin (<0.5 m) with A/C or B<sub>w</sub> horizons (Birkeland, 1999) on low terraces

**Qal4 Alluvial deposits (upper Pleistocene)**—Well-sorted cobble to boulder gravel, cross-bedded sand, and thin-bedded sand and silty sand beneath terrace remnants

14–20 m above the Rio Grande, exposed near the mouth of Los Alamos Canyon. Clasts predominantly axial-river types (see General note); locally rich in dacitic rocks derived from the Jemez Mountains. Thickness probably 4–20 m. Overlies or inset against rocks of the Santa Fe Group. Soils less than 1.0 m thick and poorly exposed; carbonate morphology is Stage II or Stage III (Birkeland, 1999)

**Qal3 Alluvial deposits (middle(?) Pleistocene)**—Well-sorted cobble to poorly sorted boulder gravel and cross-bedded sand beneath terrace remnants 25–45 m above Rio Grande, preserved at the mouth of Los Alamos Canyon. Clasts predominantly axial-river types (see General notes); locally rich in dacitic rocks derived from the Jemez Mountains. Thickness ranges from 4 to more than 15 m. Overlies and truncates rocks of the Santa Fe Group or landslide deposits. Soils 0.5–1.0 m thick contain Stage II or Stage III carbonate morphology (Birkeland, 1999) and local buried B<sub>t</sub> horizons

**QToa Older alluvial deposits (lower Pleistocene and upper Pliocene(?))**—Well-sorted pebble gravel and beds of coarse sand and overlying eolian and fine-grained fluvial deposits on mesa tops exposed from Canada de las Marias to the southeast map area. Clasts rich in axial-river types (see General note); matrix arkosic. Exposed locally from about 180–240 m above the Rio Grande at elevations of about 6,100–6,300 ft. Thickness mainly 1–5 m; overlies upper Pliocene(?) lacustrine facies of the Puye Formation. Includes an isolated outcrop north of Otowi Bridge (Rio Grande at south border of map), 145 m above the Rio Grande, that overlies Pliocene basalt and contains clasts of Bandelier Tuff pumice, axial gravel and dacitic boulders. Soils poorly exposed

## **PIEDMONT ALLUVIUM**

**Qtp Piedmont alluvium (Holocene)**—Poorly sorted cobble to boulder gravel, cross-to planar-bedded sand, boulder-rich debris-flow deposits, and eolian sediment exposed along active channels of large drainages such as Guaje and Santa Clara Canyons and their major tributaries and beneath adjacent low surfaces. Deposits generally sand-rich west of and above exposures of the Puye Formation. Exposed thickness generally less than 4 m, but as much as 10 m in borrow pits along lower Bayo and Guaje Canyons. Generally overlies Santa Fe Group, Puye Formation, or Quaternary units; locally inset against or gradational with alluvial fan deposits or older piedmont alluvium. In Bayo Canyon, <sup>14</sup>C ages from buried charcoal layers 3–6 m below the modern channel range from 4930 to 4280 yr B.P. (Riihimaki and Dethier, 1998)

**Qtp5 Piedmont alluvium (Holocene to upper Pleistocene(?))**—Cross-bedded to planar-bedded sand and pebbly sand and poorly sorted gravel beneath terraces adjacent to active channels of major drainages such as Santa Clara, Guaje, and Pueblo Canyons and their tributaries. Clasts predominantly dacite and other rock types derived from the Puye Formation and recycled Tschicoma Formation; matrix rich in subangular lithic fragments (mainly dacite) and quartzite. Deposits 0.5–5.0 m thick exposed beneath terraces 3–8 m above modern channels. Beds generally less than 0.5 m thick. Exposed thickness 3–8 m. Base not exposed. Soils

thin (<0.5 m) with multiple buried A/C and B<sub>w</sub> horizons; locally contains Stage II carbonate (Birkeland, 1999)

**Qtp4 Piedmont alluvium (upper(?) Pleistocene)**—Poorly sorted cobble to boulder gravel, sand, and silty sand. Clasts predominantly dacite; surface rich in boulders. Deposits mainly 0.5–1.5 m thick, locally as thick as 18.0 m, exposed beneath terraces 15–25 m above drainages graded to the Rio Grande between Chupaderos and Santa Clara Canyons. Overlies Santa Fe Group. Soils poorly exposed but generally thin (<1.0 m) and moderately developed with local Stage II carbonate (Birkeland, 1999) and buried B<sub>t</sub> horizons

**Qtp3 Piedmont alluvium (middle(?) Pleistocene)**—Poorly to moderately well sorted cobble to boulder gravel and sand. Clasts predominantly dacite mixed locally with quartzite and other resistant gravel derived from northern sources; matrix rich in dacite fragments and quartz. Deposits mainly 0.5–1.5 m thick, locally as thick as 20 m; exposed beneath terraces 30–40 m above present drainages graded to the Rio Grande. Overlies Santa Fe Group or Puye Formation. Best exposed between Chupaderos and Santa Clara Canyons. Soils 0.5–1.0 m thick contain Stage II or Stage III carbonate (Birkeland, 1999) and locally strongly developed B<sub>t</sub> horizons

**Qtp2 Piedmont alluvium (middle Pleistocene)**—Poorly sorted cobble to boulder gravel in deposits 0.5–3 m thick beneath isolated terrace remnants 45–60 m above present channels. Clasts predominantly dacite. Overlies Santa Fe Group near the intersection of Guaje and Los Alamos Canyons and Puye Formation at isolated exposures in Santa Clara Canyon. Soils poorly exposed, but locally contain Stage III<sup>+</sup> carbonate (Birkeland, 1999)

**Qtp1 Piedmont alluvium (middle to lower(?) Pleistocene)**—Poorly sorted cobble to boulder gravel, sand, and local eolian silty sand beneath terrace remnants at several levels between 60 and about 100 m above present channels. Clasts predominantly dacite. Deposits mainly 1–10 m thick, but poorly exposed. Overlies and locally includes areas of Puye Formation too small to show at this map scale. Mapped mainly north of Guaje Canyon

**Qtpu Piedmont alluvium, undivided (upper to middle(?) Pleistocene)**—Poorly exposed cobble to boulder gravel, sand, and local eolian deposits in the western map area. Clasts predominantly dacite derived from the Tschicoma Formation. Deposits 0.5 to more than 20 m thick beneath boulder-capped terrace remnants and elongate ridges 20–40 m above local arroyos, mainly on upland surfaces. Faulted (?) terrace remnants 40–60 m above the floor of upper Chupaderos and Garcia Canyons are mapped as Qtpu, but may be older than other deposits in the western half of the map area. Overlies deposits of the Cerro Toledo interval, lower part of Bandelier Tuff, or Puye Formation. Soils poorly exposed. Several elongate ridges of unit Qtpu appear to be topographically inverted channels active during Cerro Toledo time

**QTtp Piedmont alluvium (lower Pleistocene(?) and upper Pliocene)**—Poorly to moderately sorted dacitic cobble gravel and beds of coarse sand, boulder-rich debris-flow deposits, interbedded with eolian fine sand and silt. Basal deposits include subrounded dacitic boulders in many exposures; matrix rich in dacitic

clasts, quartz, and feldspar. Preserved on mesa surfaces more than 100 m above present grade. Thickness mainly 2–12 m. Base generally not exposed, but overlies the upper lacustrine facies of the Puye Formation (Tpl) from Guaje Canyon to north of Santa Clara Canyon; may locally overlie lower part of Bandelier Tuff at some sites. Includes areas of Puye Formation too small to show at this map scale. Soils poorly exposed but locally contain Stage IV carbonate (Birkeland, 1999)

## **ALLUVIAL FAN, COLLUVIAL, EOLIAN, AND LANDSLIDE DEPOSITS**

**Qaf Tributary alluvial fan deposits (Holocene to upper Pleistocene)**—Cross-bedded, poorly sorted cobble to boulder gravel; poorly sorted, boulder-rich debris-flow deposits; and local silt- and clay-rich fine sand exposed in active alluvial fans on slopes of 5–15° and as remnants 5–10 m above modern fans. Clasts rich in dacite and locally Bandelier Tuff. Thickness probably 4–10 m; most contacts obscured by colluvium. Overlies rocks of the Santa Fe Group and the Puye Formation. Soils poorly exposed, but locally contain Stage II carbonate (Birkeland, 1999) in decimeter-thick horizons. In lower Guaje Canyon, <sup>14</sup>C ages from buried charcoal layers in the upper 5 m of deposits range from 3450 to 2010 yr B.P. (Riihimaki and Dethier, 1998)

**Qafp Piedmont alluvial fan deposits (Holocene to upper Pleistocene(?))**—Cross-bedded sand, poorly to moderately well sorted pebble gravel, eolian fine sand and silt, and local, boulder-rich debris-flow deposits preserved in coalescent alluvial fans proximal to the Rio Grande meander belt. Clasts mainly dacite. Surfaces locally as much as 8 m above modern channels. Thickness probably 4 to more than 20 m; most contacts obscured by colluvium. Overlies rocks of the Santa Fe Group. Surface soils weakly developed; buried soils locally expose B<sub>t</sub> and B<sub>tk</sub> horizons containing Stage II carbonate morphology (Birkeland, 1999). <sup>14</sup>C ages from buried charcoal layers in the upper 5 m of deposits in the southeast map area range from 5020 to 2020 yr B.P. (Riihimaki and Dethier, 1998)

**Qpa Alluvial and eolian deposits (Holocene to Pleistocene)**—Sand, fine sand, silt, and one or more buried soils capping mesas, broad interfluvies, and adjacent low-angle slopes 60 to more than 110 m above major drainages. Beds less than 0.5 m thick and discontinuous. Matrix locally rich in quartz and sanidine derived from Bandelier Tuff. Most deposits include dacitic cobble to boulder gravel derived from alluvial deposits of the Cerro Toledo interval or from the Puye Formation. Deposits generally 2–8 m thick. Overlies lower part of Bandelier Tuff, Puye Formation, or older piedmont deposits. Soils are polygenetic, 0.5–1.0 m thick, and contain multiple buried B<sub>t</sub> horizons and local Stage IV carbonate (Birkeland, 1999)

**Qc Colluvium (Holocene to middle Pleistocene)**—Rockfall, debris-flow, and poorly sorted alluvium on steep slopes, particularly near major drainages such as Guaje and Santa Clara Canyons and along mesas capped by Bandelier Tuff. Texture and clast lithology variable. Thickness generally 3–10 m. Overlies Bandelier Tuff, Puye Formation and Santa Fe Group. Surface soils thin (<0.5 m) and weakly developed at many locations; buried soils with well-developed B<sub>t</sub> horizons or K

horizons (Birkeland, 1999) demonstrate that many deposits are polygenetic and locally older than late Pleistocene

**Qls Landslide deposits (Holocene to middle(?) Pleistocene)**—Slump complexes that consist of broken caprock of Bandelier Tuff or basalt, mantled by colluvium, mainly exposed between Los Alamos and Chupaderos Canyons and along the Rio Grande near the mouth of Los Alamos Canyon. Deposits contain massive slump blocks with coherent internal stratigraphy near source areas, and are progressively more deformed further from head scarps. Dips in slump blocks range from 10° to 50° toward head scarps. Slumps have two general origins: those involving the upper part of Bandelier Tuff and exposed north of Los Alamos Canyon failed along subhorizontal planes in lacustrine clays (principally Tpl) of the Puye Formation. Slides south of Los Alamos Canyon and close to the Rio Grande are capped by basalt and have failure plane(s) in the Santa Fe Group. Slide material overlies the Puye Formation or Santa Fe Group at most sites. Failures probably started in middle Pleistocene time as the Rio Grande and large tributaries incised rapidly through Pliocene and Miocene rocks (Reneau and Dethier, 1996). Most slides are inactive or moving only slowly. Soils are generally 0.8–1.4 m thick. Carbonate morphology (Birkeland, 1999) in colluvium overlying landslides is Stage IV at some sites, and Stage III carbonate and buried B<sub>tk</sub> horizons are present at several exposures

## **SEDIMENTARY ROCKS**

**Qct Piedmont alluvium of the Cerro Toledo interval (lower Pleistocene)**—

Pumiceous alluvium and debris flows, bedded and channel cross-bedded gravel rich in subrounded dacitic clasts as large as 100 cm in diameter, and pumice-fall deposits separated by buried soils. Contains fragments of black, aphyric obsidian from an unknown source (Heiken and others, 1986); maximum observed thickness more than 35 m in the western map area. Overlies lower part of Bandelier Tuff in most exposures; overlain by upper part of Bandelier Tuff in the western map area; forms surface material near Santa Clara Canyon. Paleocurrent directions (azimuth) on channels and gravelly cross beds range from 80° to 150°, and average about 110°. Gravel-rich sections of Qct locally crop out as ridges to rounded surfaces covered with dacitic clasts, particularly north of Chupaderos Canyon and in the western map area. Age 1.6–1.22 Ma (Spell and others, 1996)

**Tp Puye Formation (Pliocene)**—Moderately lithified pebble to cobble gravel, boulder-rich debris flows, massive to planar-bedded sand, thin (<2.0 m) beds of dacitic and rhyolitic tephra and pumiceous alluvium, lacustrine beds containing fine sand, silt, and clay, and local beds of basaltic scoria (Waresback, 1986). Gravel fraction rich in dacitic rocks derived from Tschicoma Formation sources west of the map area. Sand fraction generally rich in dacitic fragments and angular quartz grains. Paleocurrent directions (azimuth) range from 40° to 160°. At many locations, basal 10–20 m is rich in pumiceous alluvium and mudflows, and overlies one or more beds of axial-river gravel (Totavi Lentil of Griggs, 1964), each 3–8 m thick (too thin to show at this map scale) that rest on silty sand

of the Santa Fe Group. Axial gravels are about 15 m thick in lower Bayo and Guaje Canyons. In the adjacent White Rock quadrangle a 4.5-m-thick bed of axial-river gravel crops out in Los Alamos Canyon beneath 2.3 Ma basalt (Dethier, 1997) at about 6,165 ft elevation, about 80 m above the basal contact (Waresback, 1986). Paleocurrent directions in axial-river gravels range from 160° to 230° (azimuth) and average about 215°. Thickness more than 90 m, but reported as thick as 221 m in the subsurface southwest of the quadrangle (Griggs, 1964). Locally interbedded with fluvial deposits of Santa Fe Group (Chamita Formation) in eastern Guaje and Los Alamos Canyons and central Santa Clara Canyon; unconformably overlies bedded sediment of the Santa Fe Group (Chamita and Tesuque(?) Formations) elsewhere. Underlies lower part of Bandelier Tuff or piedmont alluvium that locally contains tephra of the about 1.8 Ma San Diego Canyon ignimbrite (Waresback and Turbeville, 1990). In eastern Los Alamos Canyon (adjoining White Rock quadrangle), Puye alluvial deposits and basaltic cinders are capped by a 2.57 Ma basalt (Dethier, 1997). In Guaje Canyon at 35° 54.75' N. lat. and 106° 13.37' W. long., a hornblende separate from pumice in a tephra layer about 80 m below the local top of the formation gave a  $^{40}\text{Ar}/^{39}\text{Ar}$  age of  $4.76 \pm 0.13$  Ma (WoldeGabriel and others, 2001; sample DN-97-17b). Pumice from a correlative deposit in lower Rendija Canyon gave a whole-rock K-Ar age of  $2.5 \pm 0.1$  Ma (Waresback and Turbeville, 1990). Slopes gently (0.5°–2°) eastward except in sections 16 and 17, T.19N., R.7E., where the Puye dips 12°–18° northwest to northeast in the vicinity of Miocene basalt outcrops

**Tpl Lacustrine facies (upper(?) Pliocene)**—Lacustrine beds containing fine sand, silt, and clay, a decimeter thick bed of dacitic and basaltic tephra (Waresback, 1986), and overlying sandy piedmont alluvium and debris flows separated by buried soils. Includes a bed of pebbly axial gravel 1–2.5 m thick on mesas near Santa Clara Canyon. Thickness 4–15 m; locally more than 25 m near lower Barrancas Canyon. Overlies silt-rich to coarse gravel deposits of the Puye Formation. Overlain by unit QTtp or Bandelier Tuff. Mapped where deposits are thickest or where they cap mesas from near Garcia and Barrancas Canyons to north of Santa Clara Canyon. These clays, locally as thick as 12 m, form the failure surface for landslide complexes in the south-central part of the map area

**Tsf Santa Fe Group, undivided (Pliocene to middle(?) Miocene)**—Light-brown to white, moderately lithified, massive, planar- and cross-bedded silty to coarse sandstone, red to green siltstone, and cross-bedded pebbly sand in sparse channels. Sandstone beds as thick as 4 m; channels thinner than 1 m. Coarse units locally cemented with sparry calcite. Clasts include silicic to intermediate volcanic rocks and quartzite from southern Colorado and the northern Sangre de Cristo Range and pink granite, pegmatite, and sparse sedimentary rocks from the southern Sangre de Cristo Range. Matrix arkosic. Thickness exceeds 100 m. Lies unconformably beneath the Puye Formation north of Garcia Canyon; the angular unconformity is well exposed between the Puye road and the mouth of Santa Clara Canyon. South of Chupaderos Canyon and west of 106° 09.5' W. long. in Santa Clara Canyon, light-colored unlithified to slightly lithified upper Santa Fe is rich in gravel derived from northern sources and contains beds and lenses of dacitic boulder gravel derived from the Jemez Mountains. Paleocurrent directions

mainly to the southwest and west, but locally to the south. Dips 4°–6° west and northwest, locally more than 12° near faults in Santa Clara Canyon. Correlates, in part, with the Chamita and Tesuque Formations of Galusha and Blick (1971). Age not well defined, but pre-middle Pliocene

## **VOLCANIC DEPOSITS**

### **Bandelier Tuff, Tewa Group (lower Pleistocene)**

**Qbt Tshirege Member**—White to pink slightly welded pyroclastic flows (upper part of Tshirege) and a thin (< 0.5 m) pumiceous fall unit (Tsankawi Pumice Bed), all of rhyolitic composition and containing abundant phenocrysts of sanidine and quartz and trace clinopyroxene, hypersthene, and fayalite; sanidine typically displays blue iridescence. Consists of two or three pyroclastic flows separated by pumice concentrations or thin surge deposits. Thickness generally less than 40 m, but locally more than 50 m in the western map area. Dips less than 3° to the east, reflecting the buried paleoslope. Paleoflow directions are to the east and southeast, reflecting the volcanic source to the west and northwest. Derived from the Valles caldera west of the map area (Smith and others, 1970).  $^{40}\text{Ar}/^{39}\text{Ar}$  age is  $1.22 \pm 0.02$  Ma (Izett and Obradovich, 1994)

**Qbo Upper part of Otowi Member**—White to pink, unwelded rhyolitic ash-flows containing abundant phenocrysts of sanidine and quartz, sparse mafic phenocrysts and locally abundant lithic fragments. Consists of one to three thick flow units in a compound cooling unit as thick as 40 m. Best exposed in pumice mines north of Guaje Canyon and south of access road to Puye site. Overlies Guaje Pumice Bed and Puye Formation. Overlain by pumiceous alluvium of the Cerro Toledo interval (Qct) or upper part of Bandelier Tuff. Poorly exposed or buried by colluvium where these units are absent. Derived from the Valles caldera west of the map area.  $^{40}\text{Ar}/^{39}\text{Ar}$  age is  $1.61 \pm 0.01$  Ma (Izett and Obradovich, 1994)

### **Qbg**

### **Guaje**

**Pumice Bed**—Laminated to poorly sorted compound pumiceous fall unit 10–13 m thick containing abundant phenocrysts of sanidine and quartz, sparse mafic phenocrysts, and locally abundant lithic fragments. Overlain by upper part of Otowi Member of the Bandelier Tuff. East of the Copar Pumice Mine overlies a 1.2-m-thick fall deposit of the San Diego Canyon ignimbrite dated at ~ 1.8 Ma (Waresback and Turbeville, 1990; Spell and others, 1990). Erupted from the Valles caldera west of the map area.  $^{40}\text{Ar}/^{39}\text{Ar}$  age is  $1.61 \pm 0.01$  Ma (Izett and Obradovich, 1994)

**Tb Basalt flows, thin hydromagmatic deposits and agglomerate (upper Pliocene)**—Olivine basalt and thin, underlying hydromagmatic deposits exposed in the southeast part of map area (referred to as “Otowi flow” by Galusha and Blick (1971), because of proximity to Otowi bridge). Interlayered with the Puye Formation. Source(s) located east or southeast of the map area.  $^{40}\text{Ar}/^{39}\text{Ar}$  age is  $2.57 \pm 0.02$  Ma (WoldeGabriel and others, 1996). Along upper Bayo Canyon, thin (<10 m) flows of tholeiitic basalt, breccia, and palagonitic pillow basalt erupted from buried sources to the west overlie lacustrine clays and axial river gravel of

the Puye Formation. Lies beneath thin lacustrine beds and fluvial deposits. Age of the tholeiitic flows unknown, but flows in a similar stratigraphic position in the White Rock quadrangle gave  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of about  $2.35 \pm 0.1$  Ma (Dethier, 1997)

**Tsfb Basalt flows and cinders (upper Miocene)**—Olivine basalt and thin cinder deposits exposed in southwest part of map area and at one location in Santa Clara Canyon. Lies above and locally interlayered with Santa Fe Group; underlies Puye Formation.  $^{40}\text{Ar}/^{39}\text{Ar}$  ages from flows exposed along Bayo Canyon and in an unnamed canyon to the south are  $8.86 \pm 0.05$  and  $8.78 \pm 0.09$  Ma, respectively (WoldeGabriel and others, 2001)

#### **Contact**

#### **Strike and dip of beds**

#### **Paleocurrent direction**

**Channels in lower part of Bandelier Tuff (Otowi Member; unit Qbo)**

**Piedmont alluvium of Cerro Toledo interval (unit Qct)**

**Puye Formation fanglomerate (unit Tp)**

**Puye Formation axial gravel (Totavi Lentil; part of unit Tp)**

**Santa Fe Group, upper part (undivided Chamita Formation; part of unit Tsf)**

**Santa Fe Group, lower part (undivided Tesuque Formation; part of unit Tsf)**

**Normal fault**—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side. Note: North-trending fault in sec. 16 and 21, T.20 N., R. 7 E., displaces unit Qpa and older units; colluvium of unit Qc lies against the degraded fault scarp

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